Another Perspective Towards Understanding the Forest Health Issue of Maple Decline and Mortality in the Allegheny National Forest

by Martin MacKenzie and Robert Acciavatti

A little history

In the spring of 1959 Darroll Skilling wrote for the journal American Forests, an article entitled **"Maple Blight a New Fight"** (Skilling 1959). It is from this article that the following paragraph was abstracted.

> **"Suddenly, in the summer of 1957, in Florence county WI, thousands of sugar maples began to die. So much mortality took place over a short period of time that 750,000 bd ft of timber was salvage logged from 10,000 ac. While the rate of mortality declined in 1958, it never the less continued and by the winter of 1958 another 750,000 bd ft had been marked for salvage. Upon a closer examination of the stands it became obvious that while the mortality was grouped in small patches there were also scattered dead trees throughout the rest of the stands. Further, the mortality was most severe in open stands containing mainly sugar maple."**

It takes little imagination to visualize how by changing, in the above paragraph, the place to the Allegheny National Forest (ANF), and date to 1994 would give one a sense of deja vu. In 1957 forest pathologists were familiar with maple twig die back, and as this seemed to be a new phenomenon they coined the term "Maple Blight" It soon became obvious that this was not a blight in the sense of, potato late blight, chestnut blight, or the blight of dogwood. It was in fact a complex of several interacting biotic and abiotic agents and as a consequence the term maple blight was dropped in favor of the term "Maple Decline". The concept of pollution mediated, species, forest, and even global declines obtained much political and popular press through the 1980's. So much so that the German word "Waldsterben" (forest dying) came into the forest pathology lexicon. In a November 1994 review of Waldsterben, Skelly and Innes (1994) concluded that the interpretation of Waldsterben presented in the scientific press less than a decade earlier (Schutt and Cowling 1985) is no longer applicable. Further the "classic Waldsterben", as perceived by the popular press has never existed (Manion and Lachance 1992).

As the 1980's came to a close Millers et al (1989) documented the history of hardwood declines in the Eastern United States. They reported that between 1912 and 1986 there had been at least 26 major episodes of maple decline, of which at least four had taken place in Pennsylvania. The 1990's opened with an objective re-evaluation of the concept of "Forest Declines". On the 9th of August 1990 the Canadian and American Phytopathological societies brought together many of the world experts on the subject of forest declines. This meeting culminated in the publication of a book entitled "Forest Decline Concepts" (Manion and Lachance eds 1992). Six of the papers in this volume

have been cited in this essay (Houston 1992, Mueller-Dombois 1992, Skelly 1992, Allen et al 1992, Manion and Lachance 1992, and Auclair et al 1992).

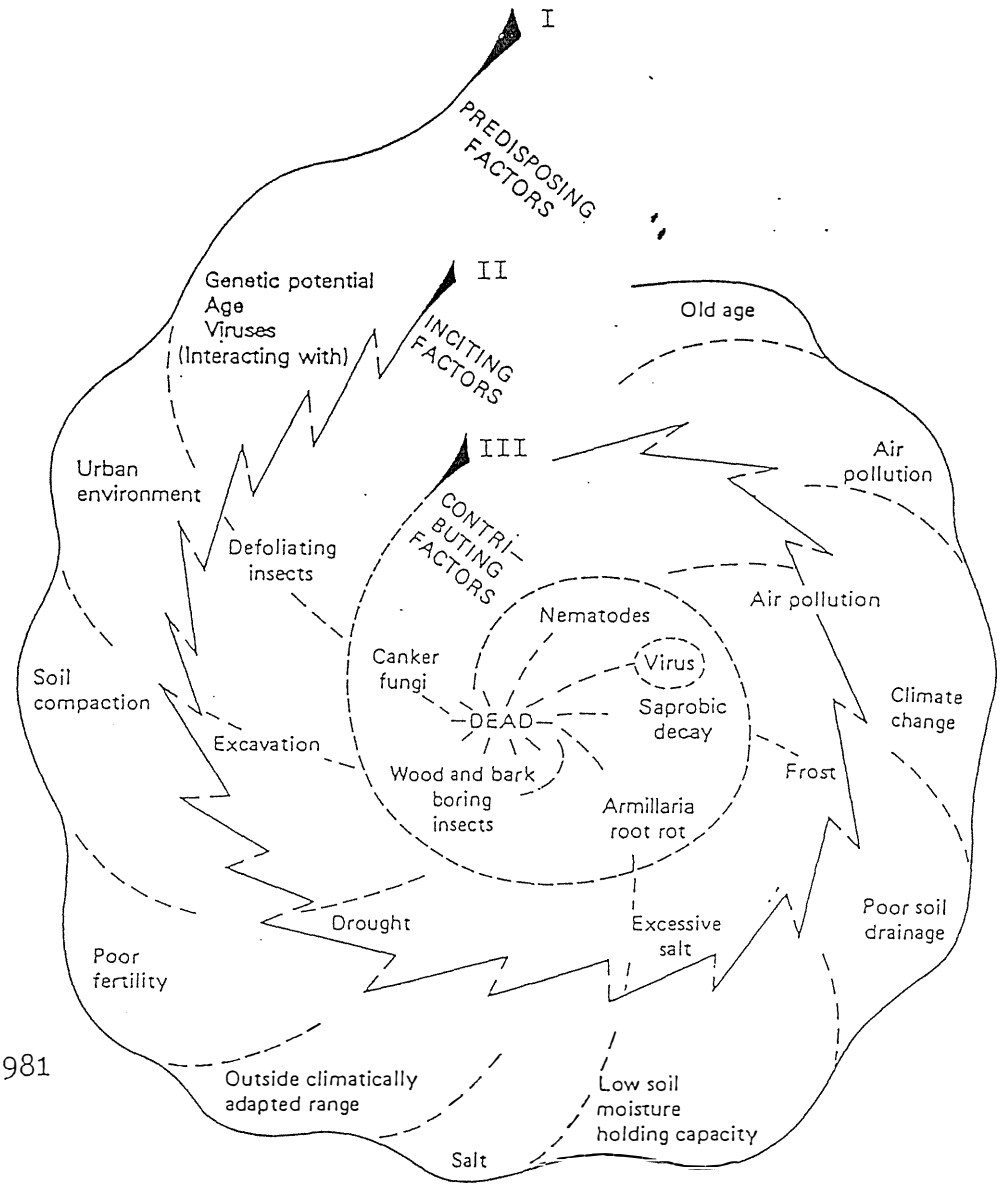
Skelly (1992) makes the point that the term "Forest Decline" is a misnomer, for these episodes are declines of usually a single species and not of a forest per se. In many cases as some species are declining there will be others in the ascendancy. It is regrettable that it is the dying species that gets all of the attention. These episodes should be described as episodes of a single species decline, on the ANF we have an episode of sugar (Acer saccharum Marsh) and red (A. rubrum L.) maple decline. This is not to say that the factors predisposing one species to decline might not also stress other species. In the case of the ANF a local decline of white ash (Fraxinus americana L.) has been observed (R. White personal communication 1994). To balance these reported declines of ash and maple the authors would like to point out that the ANF is now growing some of the healthiest striped maple (Acer pensylvanicum L.) either has ever seen. "Nature abhors a vacuum" and is not fussy about filling it with a non-commercial species.

The Decline Disease Spiral

Several models have been proposed to explain past episodes of tree species decline and death. Houston (1992) favors a model that places emphasis on the role of secondary pathogenic organisms. Muller-Dumbois (1992) offers a model which places emphasis on the importance of genetics and aging of tree species. While in a third the emphasis is placed on the role of extremes of temperature (Auclair et al 1992). In his 1981 pathology textbook Manion (1981) developed the concept of a decline disease spiral which is probably the best model available to explain the observed maple declines. Manion's 1981 decline disease spiral (figure 1) is provided here to explain the maple decline on the ANF. Manion (1981) envisages three parallel, ever-tightening, inwardly spiralling trains of events. The ultimate center of these spirals is tree death. However, should the decline go into remission, the spiral will unwind and the tree will recover. Bauce and Allen (1991), caution that such reversals in maple decline are only possible in the early stages, before the secondary organisms (contributing factors) have invaded the stressed trees. It may well have been this observation that led Houston (1992) to place his emphasis on the role of the secondary organisms. In a biologically diverse forest the spiral on one species might be tightening, while at the same time the spiral on another might be unwinding as it responds to the growing space made available by the demise of the first species. For example as the Beech Bark Disease (BBD) spiral tightens on American Beech (Fagus grandifolia L.) on parts of the Monongahela State Forest the understory of red spruce (Picea rubens Sarg.) appears to be making regenerative progress (M. MacKenzie, personal observations). On the ANF the past two years of open winters may have tightened the spiral on the maples, yet they appear to have unwound it on the beech; for the very low temperatures have killed many of the scale insects that incite the BBD decline (M. MacKenzie, personal observations).

A distinction must be made between **forest health** and **forest resilience.** Take the case of chestnut blight impacting a chestnut/oak forest. No amount of biological diversity would have saved the chestnut. The presence of oaks did

Manion's Decline disease Spiral for Maple on the ANF



After Manion 1981

Figure I

I Predisposing Factors

Those factors to which the maples have not adapted (ie. those factors which indicate that the species is growing in the wrong place at the wrong time). These factors include the recently introduced insects and fungi to which the host has not had sufficient evolutionary time in which to adapt.

II Inciting Factors

Those agents of primary damage that are part of the natural environment. Once the ecosystem has had time to adapt to introduced species they should be considered as being inciting factors.

III Contributory Factors

Those agents of secondary damage that can only attack stressed trees

not make the chestnut less susceptible to the blight. What they did was ensure the continued existence of a forest. Biological diversity makes a forest more resilient, not necessarily anymore healthy. A pine plantation can be very healthy, but lacking biological diversity, it has reduced resilience should it become attacked by a virulent pine pathogen. In the case of the relatively diverse ANF, decline of the maples may lead to the release of suppressed trees of other species. In the short run the forest will survive. Long term recovery depends upon there being adequate recruitment into the pole class of other species and an adequate source of maple seed from which to rebuild the maple populations once the decline phase passes. Data currently being analyzed by the ANF would seem to indicate that this view, of long term forest recovery may be overly optimistic (R. White, personal communication). These data would seem to indicate that there may be inadequate seedlings of several species available from which to mount such a recovery.

A distinction is drawn between "average droughts" and those which combine a longer than average duration with a greater than average severity. The former type is placed in the contributing factors class and the latter is classified as an inciting factor. In reality, there exists not a pair of drought impacts but a spectrum of drought impacts. In their review of "tree death as an ecological process", Franklin et al (1987) solved this problem by reducing the "Manion decline disease spiral" to a single spiral and called it a "mortality spiral". While this approach works well for the botanically simpler old growth forests of the Pacific Northwest, a three tiered spiral (despite it's problems) is more appropriate for the ANF.

Components of the Maple Decline Spiral on the ANF

TABLE I The specific factors involved in the red and sugar maple spirals on the Allegheny National Forest.

I Predisposing Factors	II Inciting Factors	III Contributory Factors
* A succession of droughts in 1960's, 1988, 1991	* an isolated yr of drought	* Anthracnose fungi 1994
* Pear Thrips 1985-1994	* Looper Defoliation 1960's-1994	* Sugar Maple Borer omnipresent
* Acid Rainh ?-1995	* Leaf Rollers early 1970's-1994	* Armillaria Root Rot ubiquitous
	* Elm Spanworm 1991-1993	
	* Forest Tent Caterpillar 1993-1994	
	* Open Winters 1993-1995	

I PREDISPOSING FACTORS

* Drought

The outer spiral of Manions model contains the predisposing factors. In the case of maples on the ANF this spiral will include the several years of chronic droughts (Kolb and McCormick, 1993). These are events that are outside the generally adapted range of the species. Intermittent short term droughts would be placed in the second spiral. A review of the positive association between drought and outbreaks of plant-eating insects is provided by Mattson and Haack (1987). They conclude that droughts:

(1) provide a more suitable environment for the growth and development of insects.

(2) increase insect (and plant pathogen) survival.

(3) elevate plant nutrient levels (especially nitrogen) achieved in part by reducing the volume of water in which the nutrients are dissolved.

(4) lower plant defences.

Water stress results in stomatal closure and a reduced transpirational rate which in turn leads to an increase in plant temperature. While in most cases this increase is of the order of 2-4^{o} C, differences as great as 15^{o} have been recorded (Mattson and Haack 1987). The thermal optima for some enzyme systems of some plant eating insects are often quite high and a small increase in temperature can elicit a large response in the activity of insects (Martin et al 1980). Under such conditions plant eating insects may grow faster, grow larger, suffer less mortality, and lay more eggs per unit of plant material eaten.

The elevated temperatures of drought may favor the the growth of the exo- and endosymbionts of insects to an extent that the growth of the insect is favored over that of the pathogens of the insect (Mattson and Haack 1987). For example, the temperatures may favor the wilt and stain fungi that are a part of successful colonization by many wood and bark inhabiting insects. Similarly the lowered humidity may prevent fungal spore germination and in this way slow the build up of entomophagous fungi that usually follow an outbreak of defoliating insects. Most plants lower their osmotic potential during drought. They do this by by accumulating inorganic ions, amino acids, sugar alcohols etc (Kramer 1983). During droughts, while total nitrogen in roots and above ground parts may decline, the level in the youngest above ground parts may increase (Mattson and Haack 1987). The new leaves may be smaller yet be of a higher quality food for faster growing young insects. While water stress will slow the development of cells in growing tissues it will also lead to cell wall thickening and an accumulation of secondary metabolites such as terpenes, alkaloids and waxes. Mattson and Haack (1987) speculate that the combination of elevated temperatures and increased nutritional quality of drought stressed leaves have a synergistic effect which leads to an enhanced insect detoxification of otherwise inhibitory drought induced plant metabolites.

* Pear Thrips plus a series of droughts.

Kolb and McCormick (1993) have reviewed the health of 4 stands of Allegheny Hardwoods in the NW corner of Pennsylvania. Two of the stands were in the ANF and the other two were in the Susquehannock State Forest. All four fell within Bailey's ecoregion section, 212G, the Unglaciated Allegheny Plateau (McNab and Avers 1994). After computing the BAI of the sugar maple component Kolb and McCormick (1993) concluded that it had been declining since the late 1960's. While the BAI was generally declining, the BAI of trees they designated as "declining" was falling faster than that of their "healthy" trees. It is unfortunate that they did not look to see if the BAI of the American beech, black cherry (Prunus serotina Ehrh.) or white ash had increased in the same time period. Their working hypothesis is that the decline began with a series of defoliations and summer droughts in the mid 1960's through the early 1970's; and that these stresses were compounded by the introduction of the bud rasping and scraping pear thrips (Taeniothrips inconsequens Uzel.). Although this insect was recorded from California in 1904, it was not observed feeding on maples in Pennsylvania until 1979 (Laudermilch 1988). Pear thrips was first observed causing heavy defoliation of sugar maple on the ANF in 1989 (K. Riddle, personal communication). Yet, it may have been causing localized damage on the Bradford Ranger District as far back as 1979 (R. Acciavatti personal communication).

* Acid Rain

Although the authors have stated that many researchers have over-sold the concept of manmade pollution mediating wholesale forest declines, serious reflection indicates that there must be a role for acid rain in any model of decline. While the spiral proposed by Manion (1981) places acid rain in both the predisposing and inciting factor spirals, the authors would place it in the spiral of predisposing factors, on the grounds that the forest species are not likely to have a yet evolved to accommodate this changing aspect of their environment. Foliar analysis of maple trees has shown a deficiency of both Ca and Mg which may be related to the predisposing factor of acidified rain (Kolb and McCormick, 1993). Professor William Sharpe of Pennslylvania State University has made available to the supervisor of the ANF two (as yet) unpublished manuscripts which provide more supporting evidence of a role for acidified rain in Pennsylvanian forest declines. Both of which underline the need for additional studies in this field.

II INCITING FACTORS

* Defoliating insects

The mode of action of most defoliating insects is similar, they divert tree resources for their own uses. Leaf tissue is redirected to produce insect tissue. Having its photosynthetic tissues reduced the tree has to draw upon reserves to produce new leaves and as the reserves of the tree are consumed it

is driven further down the decline spiral. In discussing the disease decline spiral on the ANF the authors have chosen to use only two examples of the native defoliators available for consideration.

* Elm Spanworm

In Pennsylvania, recent epidemics have occurred in Clearfield County in 1974, Potter County in 1976, and Wayne, Lackawana plus Monroe Counties in 1980, each of which lasted one or two years before collapsing naturally (Quimby personal communication 1993). The most recent outbreak within the ANF boundary began in 1991 and resulted in the defoliation of about 23,000 acres. About 28,500 acres were defoliated in 1992, and the amount of defoliation increased to about 260,000 acres in 1993. About 7,500 acres have been defoliated three times, and more than 51,800 acres have been defoliated twice. The Pennsylvania Department of Environmental Resources (DER), Division of Forest Pest Management, reported moderate to severe spanworm defoliation throughout Pennsylvania in 1993 totalling approximately 729,730 acres (PA-FPM, 1993), and about 1.1 million acres in 1994 (PA-FPM, 1994).

During the most recent infestations of elm spanworm (Ennomos subsignarius, Hubner) on the ANF, American beech seems to be the initial preferred species. With such high spanworm populations, eventually most deciduous tree species were affected, including black cherry. In 1992 it was noted in the Highland area of the Ridgway Ranger District that following the defoliation of beech, the spanworm attacked red maple and then moved onto the sugar maple. In 1993, Ridgway Ranger District personnel noted that after beech defoliation, sugar maple was attacked before red maple (S. Wingate personal communication, 1993).

* Forest Tent Caterpillar

During 1994 the forest tent caterpillar (Melacosoma disstria Hubner) was one of the major defoliating insects on the ANF. It was estimated that some 18,000 acres had been defoliated in that year (Omer 1995). Further, if left unchecked Omer (1995) predicts that the defoliation will expand to cover some 58,000 acres in 1995. While this insect can defoliate sugar maple, oaks, aspen, cherry, ash, and basswood, its hosts of preference are sugar maple and aspen.

* Open winters

While reviewing the the Canadian literature on forest decline Allan Auclair and Denis Lachance came upon an unpublished 1959 file on birch decline in Quebec. It was the work of Dr. Rene Pomerleau, who had retired from the Laurentian Forestry Centre in 1970. Thirty two years after he had written the work, the file was published as "Experiments on the causal mechanisms of die back on deciduous forests in Quebec", Pomerleau (1991). Pomerleau's theory became the base upon which Auclair et al (1992) built their theory of "Climatic pertubations as a general mechanism for forest decline". Pomerleau theorizsed that dieback episodes were the result of anomalous climatic phenomena. He

attributed the hardwood diebacks of the 1920's to deep soil frost penetration in years of open winters. He suggested that dieback was the result of frost-kill of roots and severing of roots by ice lense formation. In closed winters the roots would be protected by a deep insulating cover of snow. In an appendix to his paper Pomerleau outline an experiment in which he kept one of a pair of an experimental plots snow free, and subsequently observed maple dieback only in the snow free plot. While it must be remembered that this was an unreplicated study, it is worthy of note that the winter previous to the onset of the maple decline on the ANF had been described as open and there were reports of significant frost heave on the forest (Houston personal communication 1994)

III CONTRIBUTING FACTORS

* Anthracnose fungi

Working in the Susquehannock State Forest, Nash et al (1990) were able to show that on dominant or co-dominant sugar maple trees with a history of pear thrips damage a Discula fungus could be consistently recovered from damaged leaves. Stanoz (1993) went on to demonstrate that the fungus (now known as Discula campestris (Pass) v Arx) could cause seedling mortality when its spores were sprayed onto wounded leaves. He concludes that although the fungus is pathogenic it requires the wounds caused by the thrips if it is to kill leaves. It is this requirement for a preexisting wound that has the authors place this agent in the contributing spiral and not the inciting spiral. The third spiral includes the secondary organisms such as the Sugar Maple Borer (Glycobius speciosus Say), Armillaria root rot, Discula campestris and other anthracnose fungi. Quimby et al (1994) observed that several anthracnose fungi were blighting new leaves as the trees tried to refoliate in the warm wet summer of 1994.

* Sugar Maple Borer

The long-horned wood boring Sugar Maple Borer is the single most injurious insect of sugar maple wood. While unaided it might not kill trees, it does have a deleterious impact when acting in conjunction with other agents. It prefers to attack intermediate or codominant trees of reduced vigor. This may well be exactly what we have in some of the areas of the ANF being considered for salvage. The frequently transverse or horizontal feeding galleries of the

tunneling larvae become the entry courts for the stain and decay fungi usually associated with successful attacks. Where these tunnels come close to girdling a branch the reductions in sap flow that they cause can lead to crown discoloration, dieback and breakage of portions of a trees crown (Hoffard and Marshall 1978, USDA 1971). As a consequence of Beech Bark Disease replacing beech with maple, Allen (1987) has speculated that not only has the sugar maple borer population been increased but also has it's potential to be destructive in a biologically less diverse forest.

* Armillaria Root Rot

In a history of hardwood declines in the Eastern United States Millers et al (1989) cited 56 instances of oak decline between 1856 and 1886. In 34 of these cases an abiotic stress (usually drought) and or defoliation was considered the primary cause with Armillaria and Agrilus as contributory agents. In 22 of the 34 cases they were recorded as working together. The Agrilus was most likely to have been the two lined chestnut borer, Agrilus bilineatus Weber. In contrast, the Armillaria could have been one of many species (Anderson and Ulrich 1979). For this reason the etiology of the decline will vary with the pathogenicity of the Armillaria species involved. As far back as 1977 Wargo was cautioning against categorizing the agents of these declines as either primary or secondary and was proposing a more holistic approach to the problem. Early reports tended to place Armillaria in a secondary role as its frequency was underestimated. When whole trees are excavated, as in Wargo (1977), and the total root system examined rather than just the root collar region the presence of Armillaria is more accurately estimated. On dead and dying oaks the fungus may be found 1.5 to 2.0 m from the root collar but not at the root collar.

There is no reason to believe that this fungus will behave any differently in maple decline than it did in an oak decline (Millers et al 1989, Wargo and Houston 1974). The role of the two lined chestnut borer in the oak decline scenario may be taken over in the maple decline scenario by the sugar maple borer (Bauce and Allen 1992). In an 1964 assessment of a "Maple Blighted" site (Houston and Knutz, 1964) reported that 70% of the trees marked for salvage were infected by Armillaria whereas only 32% of the "healthy" trees were infected. Thus 70% of the root systems of blighted trees would have been able to serve as Armillaria inoculum sites for future mortality . Indeed, these authors maintain that it was this inoculum that accounted for most of the delayed mortality that occurred for up to three years after most of the serious damage. In times of a primary decline (ie. when the spiral is tightening) the fungus will build up (saprophytically) on the root systems of dying trees and await the next stress episode and then (using its rhizomorphs) move out to attack a new host. It is usually successful for it is drawing upon the food base of the roots of previously killed or stumps of previously salvaged trees.

The role of this secondary organism is well documented in the writings of Wargo (1977) and, Houston and Wargo (1974). Suffice it to say that on the ANF this fungus is both ubiquitous and opportunistic. Further it will behave as it has done in other forest settings (MacKenzie and Self, 1988). For further discussion see the later section on "Pathological predictions...".

Prognosis for the surviving trees in the declining stands.

In terms of the Manion model (Figure 1) there is only one question to be asked: will the red and sugar maple spirals on the ANF tighten or will it relax in 1995?

Returning to our starting point, the highlighted paragraph on the first page (Skilling 1959) , and the first report of a maple decline, we find that in Florence county Northern Wisconsin, in the summer of 1958 there was little defoliation or mortality of the residual maples. The majority of the mortality took place in 1957 and after 1958 the stands recovered. In this case the spiral unwound. While there was little defoliation in 1958 there had been been severe defoliation by at least two species of leaf roller (Sparagnothus acerivorana MacKay and Acleris chalybeana Fernald) and a webworm (Tetrolopha asperatella Clemens) prior to the onset of mortality (Giese and Benjamin, 1964). In this case the inciting defoliators had been identified. Although the role of Armillaria had been investigated there was no strong evidence of it acting as a contributory factor. Apparently the maples recovered before this fungus could push the trees beyond the point of no-return.

The best candidate for the role of secondary agent in this current maple decline on the ANF are the anthracnose fungi that blighted the refoliating trees during the warm wet summer of 1994 (Quimby et al 1994). Unlike the soil inhabiting Armillaria, the fate of these foliar pathogens is at the mercy of the weather.

At this stage there has been little evidence to suggest that the maple borer is going to cause significant mortality in the summer of 1995.

When the map of the areas of predicted moderate to heavy forest tent caterpillar defoliation (Omer, 1995) is overlain with the map of areas of heavy sugar maple mortality (Palmer, 1994) it is obvious that over half of the areas of heavy mortality are also areas predicted to be defoliated again in 1995. It would be safe to predict that if mortality is to continue in 1995 then it would be in the areas of overlap, for here the spiral is predicted to tighten. Spraying these areas to control the forest tent caterpillar should help unwind the spiral on the surviving stressed sugar maples.

The winter of 1994/95 has been open and relatively mild. In the last half of the winter the jet-stream drew very cold air down from Canada and over the ANF. In light of Pomerleau (1991), the question to be asked is, were the conditions right for the development of significant ice lens formation? If the answer is yes, the work of Pomerleau predicts a continued tightening of the spiral on the residual maples, resulting in more mortality in the summer of 1995.

Two ANF silviculturists, L. DeMarco and S. Wingate (personal communications, 1995) have reported that there appears to be a correlation between the

incidence of maple dieback and the track of a tornado that impacted a portion of the ANF. In this case the suggestion is that, the excessive stem movement that the tornado caused may have snapped roots and lead to a result similar to the ice lenses proposed by Pomerleau (1991).

Pathological predictions in the damaged stands of the ANF

It is not thought likely that, "to salvage or, not to salvage" will in any major way effect the outcome of Armillaria root rot development on the ANF (D. Houston and T. Shaw personal communications). As the fungus lives largely below ground and the salvage is an above ground operation, the fungus will not be impacted. If it is assumed that the models of Kolb and McCormick (1993), Wargo and Houston (1974), and Bauce and Douglas (1992) are applicable to the salvage areas of the ANF, then we can safely assume that a portion of the root systems of the declining trees are already colonized by Armillaria. Once the trees die (regardless of whether they are salvaged or not) the fungus will rapidly expand to cover a large portion of the root system. From its base on the root systems of killed trees or the stumps of salvaged stems the fungus will be able to expand and attack any residual trees (be they maple, beech, or black cherry) which come under the combined stress of a drought and a defoliating insect. Thus the future health of these stands is in part set by past health, and it becomes the foresters job to ensure that the stands stay stress free as far, and as long as is possible.

While it has already been stated that the sugar maple borer will cause little direct mortality, it will have an adverse impact on grade recovery. The grain deviations and fungal staining resulting from insect tunneling will prevent the wood from being used in an exposed place in high valued maple furniture (Levitin 1976). In one mill study conducted in NY state it was shown that in one sale, 9.6% of the lumber and 19% of future crop trees had to be culled as a direct result of this insect (Anon 1977). In a related sale 10-15% of grade defect and cull was attributed to this insect with 30% of the residual trees having to be culled (Bailey 1978).

As a cautionary note, it is pointed out that many of the residual "healthy" maples will have been stressed for several years. As a consequence, their ability to seal wounds will have been compromised (Wargo 1977). For this reason, future silvicultural entries into the declining stands must be carried out with caution, so that the residual stems are not wounded. These slower sealing wounds might not lead to mortality but they will lead to staining, decay, and a lower grade recovery at final harvest. While Houston et al (1990) list several candidate fungi for this role, one of the most probable would be the sapstreak fungus, Ceratocystis virescens (Davidson) C. Moreau (Houston 1993). Just as future health will be dictated in part by past health, future grade recovery will be influenced by past wounds.

The fate of trees recovering from dieback.

While some trees will go close to death and eventually refoliate in 1995, their future growth will reflect the damage of the reversible decline of 1994. In those trees which die back to the main stem and resprout from below the level of the 1994 crown we can eventually expect that the entire volume of the 1994 bole will be; at least discolored and, at worst totally decayed. Shigo (1984) developed his concept of CODIT (Compartmentalization Of Decay In Trees) in species like the sugar maple. He concluded that after an injury the maple

walls off the wound with decay and or stain being confined to the wood that existed at the time of wounding, which in this case could (under worst case scenario) be the 1994 bole. As sugar and red maples are relatively good compartmentalizers of decay this is the worst case scenario and assumes that the trees are retained in the stand until they approach their pathological rotation age. In some areas of the ANF it is planned to harvest the recovering trees within the next 80 years and thus the loss will not be total. However, we can expect a significant loss in grade recovery from trees experiencing dieback to the main stem. Where the dieback is only of major branches the decay will take longer to reach the bole and any grade loss may be due largely to fungal staining. In other areas where no harvest is planned degrade can not be considered a loss, for here, degrade and mortality must be considered a natural part of the ecological process that leads to the rebirth of a new forest from the legacy of the coarse woody debris of an old forest.

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